TITLE OF THE INVENTION

Multipoint Short Range Radio Frequency System

BACKGROUND OF THE INVENTION

001   The invention relates to the field of low power, short-range wireless data transmission between hosts (such as video game consoles, consumer electronic devices or data devices) with subtended base transceivers and remote peripherals and the coordination of multiple such systems operating within the same radio frequency domain. "Domain" is defined as devices that are within a local area where their radio transmissions can be heard by all radio frequency (RF) enabled devices. Domain is also referred to as a radio frequency operating range in the description of the invention.

002   The usefulness of radio frequency wireless solutions is well known. Such solutions eliminate the masses of wires interconnecting the various interfaces found on electronic devices. This results in more flexible and cost effective options for upgrades and reconfiguration of devices. Further radio frequency wireless versus infrared wireless solutions are not typically impacted by objects present in the line of site between transmitters and receivers, making RF configurations more flexible and less intolerant of physical environment features.

003   With the increasing visibility and utility of wireless technology for office and home applications, two very important issues arise. First the level of radio frequency interference continues to increase, introducing the need for more robust approaches to digital signal transmission for short range applications.

004   Second the pent up demand for wireless functionality in the home represents a significant opportunity if cost/performance design issues can be adequately addressed. Although systems need to be increasingly robust, subscribers are not willing to pay a significant price premium for such technology.

005   Cellular or other conventional wireless applications purposely operate in larger cells or RF areas typically designed to minimize overlap to the amount required for

continuous signal reception. The type of applications to which this invention relates, however, are typically base transceiver systems in close vicinity due to the sharing of a common host system ports or the close location of multiple host systems with devices in dense multi-tenant dwellings configurations or personal area networks.

006   RF saturation problems occur when base transceivers are in close proximity. If one base transceiver is transmitting, while another is listening, the receiver of the second base transceiver will saturate even though it may be operating on a different frequency than the first transceiver. This occurs because the out of band signal from the first transceiver is sufficiently powerful to be seen as a signal for the second transceiver.

007   To resolve this problem a method of synchronizing adjacent base transceiver polling transmissions is required. The invention provides a robust, distributed approach to provide such synchronization without a connecting wired backbone and/or a centralized coordinating device.

008   Such an approach is not dependent upon having a primary base transceiver or master controller as the coordinator. Further in this approach no voting scheme is required to replace a primary base transceiver that can no longer act as the coordinator of a system of base transceivers.

009   Conventional systems of this nature include the wireless LAN implementation of 802.11. Operating in an infrastructure mode, 802.11 uses a beacon frame transmitted from a central access point to keep wireless stations synchronized. In another configuration of 802.11, an ad hoc configuration of peer-to-peer base transceiver communication is supported, but one of the associated machines needs to be elected to be the base station (master) of the network.

010   The invention has particular utility in gaming applications. United States Patent No. 5,561,419 to Sasaki et al., (1996), "Wireless Communication Apparatus and Game Machine Using the Same" describes a master slave polling configuration for gaming in which multiple peripherals are time division multiplexed to a single host. Information is

passed from the peripherals to the base transceiver ("master unit") in a unidirectional fashion. No spread spectrum techniques are used. The configuration described relies on manual time delay configuration and is susceptible to environmental noise.

011   United States Patent No. 5,806,849 to Rutkowski, (1998), "Electronic Game System with Wireless Controller" presents a long range, low speed uni-directional RF system for gaming. The system used multiple channel transmission frequencies, statically assigned, and used a single receiver to poll individual controller channels.

012   United States Patent No. 4,531,740 to Green et al., (1985), "Remote Control System for a Video Computer Game" disclosed a remote controller system for a video computer game using RF transmission as a communication mechanism. The Green system was for a fixed, application specific controller and electronic game device configuration and did not provide for other uses. Green does not disclose use of spread spectrum and channel quality measurement techniques.

013   The invention also has application for wireless consumer electronic devices. United States Patent No. 5,764,648 to Yamane et al., (1998), "Method and Apparatus for Generating a Transmission Timing Signal in a Wireless Telephone" describes a master slave system wherein a stand alone base station and wireless telephone pair exchange data packets and peripheral timing is coordinated by a base station synchronization signal. The system also describes how during reception in a first channel, the channel quality of another vacant channel is measured. Channels are seen as being either good or bad.

014   The invention also has application in wireless data communication. United States Patent No. 5,862,171 to Mahany et al., (1999), "Radio Frequency Communication Network Having Adaptive Communication Parameters" describes a system with mobile transceivers communicating with a radio base transceiver in which the system adapts to operation conditions by varying the spreading codes used, changing hop frame lengths, coding and interleaving in frequency-hopping spread spectrum communications and adjusting data packet size.

015   United States Patent No. 5,696,903 to Mahany, (1997), "Hierarchical Communications System Using Microlink, Data Rate Switching, Frequency Hopping and Vehicular Local Area Networking" describes a wireless RF system of multiple base stations and associated multiple peripheral devices that are controlled and coordinated over a common network by a central host computer.

016   The invention also has application in telecommunications. United States Patent No. 6,154,655 to Borst et al., (2000), "Flexible Channel Allocation for a Cellular System Based on a Hybrid Measurement-Based Dynamic Channel Assignment and a Reuse-Distance Criterion Algorithm" describes a method of dynamically allocating channels in a cellular system using a measurements-based list of candidate channels and a dynamic reuse-distance algorithm.

SUMMARY OF THE INVENTION

017   There is thus provided according to an aspect of the invention, a multiple point radio frequency (RF) transmission system that can be used for linking gaming applications, consumer electronics devices and personal computer data devices to remote peripherals.

018   According to certain aspects of the invention, the invention uses a polling-response architecture combined with spread spectrum techniques where a base transceiver is designated as the master and one or more peripherals serve as slaves.

019   The base transceiver may be attached to a host system and transmits messages to and from this host from a remote peripheral (single-point configuration) or peripherals (multipoint configuration). Base transceiver and peripheral(s) are arranged in a master slave wireless configuration utilizing a poll and response data transmission method.

020   A hybrid spread spectrum transmission method is preferably used. According to a further aspect of the invention, there are provided methods for synchronizing and

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coordinating the RF transmissions of multiple independent base transceivers and peripherals in close vicinity with overlapping RF domains.

021   Applications for the invention include short distance wireless RF video game controllers, wireless RF remote controls and peripherals for consumer electronic equipment such as set top boxes and stereos, and wireless peripherals and data links for personal computers.

022   Therefore, in accordance with an aspect of the invention, there is provided an RF system, comprising an RF section, a processor operably connected to the RF section, an input/output subsystem operably connected to the processor; and the processor being configured to control transmission of sync signals from the RF section in response to receiving sync signals at the RF section from another RF system.

023   In accordance with a further aspect of the invention, there is provided a method for exchanging information between transceivers, the method comprising the steps of transmitting and receiving signals, including sync signals, from a first base transceiver; and controlling transmission of sync signals from the first base transceiver in response to receiving sync signals from another base transceiver.

024   In accordance with a further aspect of the invention, there is provided an RF system, comprising an RF section, a processor operably connected to the RF section; an input/output subsystem operably connected to the processor and to a game console; and the processor being configured to scan a set of channels for at least one channel suitable for communication with another RF system.

025   In accordance with a further aspect of the invention, there is provided a method of exchanging game information between transceivers, the method comprising the steps of scanning a set of available channels for at least one channel suitable for communication between the transceivers; and exchanging game data between the transceivers using at least one suitable channel.

026   In accordance with a further aspect of the invention, there is provided an RF system, comprising an RF section, a processor operably connected to the RF section; an input/output subsystem operably connected to the processor and to a user interface, a manually operated switch operably connected to the processor, and the processor being configured to respond to operation of the manually operated switch to cause the RF section to transmit a request selected from the group consisting of a request for a change of time slot assignment for communications between the base transceiver and the RF system and a request for a change of base transceiver with which the RF system is to communicate.

027   In accordance with a further aspect of the invention, there is provided a method for changing communications between a base transceiver and an RF system, the method comprising the steps of assigning a time slot to a peripheral RF system for responding to a first base transceiver; and manually switching to a different time slot for sending information to the base transceiver.

028   In accordance with a further aspect of the invention, there is provided a method of exchanging data between transceivers, the method comprising sequentially repeating the steps of transmitting a polling volley from a base transceiver to plural peripheral transceivers, wherein the polling volley contains sequential packets addressed to the plural peripheral transceivers; and the plural peripheral transceivers responding in order to the polling volley after the termination of the polling volley.

029   In accordance with a further aspect of the invention, there is provided a method of exchanging data between plural base transceivers operating on a common frequency assignment and at least one peripheral transceiver associated with each base transceiver, the method comprising the steps of each of the plural base transceivers transmitting a sync packet at times at which none of the other of the plural base transceivers are transmitting a sync packet, each of the plural base transceivers listening for sync packets from others of the plural base transceivers; and each of the plural base transceivers adjusting a respective time clock associated with the base transceiver according to information contained in the sync packets.

030   In accordance with a further aspect of the invention, there is provided a method of exchanging data between transceivers, the method comprising sequentially repeating the steps of during a polling volley, each of plural base transceivers transmitting a data packet in different time slots on a single channel to a corresponding one of plural peripheral transceivers; and the plural peripheral transceivers responding in order to the packets in the polling volley after the termination of the polling volley.

031   In accordance with a further aspect of the invention, there is provided a method of synchronizing N plural transceivers, the method comprising the steps of:

each of the N plural transceivers transmitting a sync signal when none of the others of the N plural transceivers are transmitting a sync signal;

each of the N plural transceivers transmitting data in polling volleys;

each of the N plural transceivers transmitting a sync signal each N+1 polling volleys; and

each of the N plural transceivers synchronizing to the sync signals from the other base transceivers.

032   The input/output subsystem is operably connected to a host selected from the group consisting of a video game console, a set top box, a consumer electronic device, a computer and data networking equipment. The processor is preferably configured to cause:

a) the RF section to transmit polling volleys in a time division manner;

b) the RF section to transmit a sync signal in a sync slot associated with a polling volley

c) the RF section to transmit a sync signal in association with a first polling volley and then listen for sync signals from other RF systems in association with a subsequent polling volley;

d) the RF section to delay sending a sync signal when a sync signal is received from another RF system;

e) the RF section to advance the sending of a sync signal when a sync signal is no longer received from another RF system; and

f) to receive responses from peripherals transceiver in time slots associated with each polling volley, in which each peripheral transceiver is assigned a specific time slot.

033 A visual indicator may be operably connected to the processor for indicating a change in assignment of a time slot for a peripheral transceiver. Signal transmission preferably uses frequency hopping, with different transceivers on different frequencies at the same time. Random delay on power up is preferably used to avoid clashing with another base transceiver.

034 Channels are preferably selected for use that have a lower degree of impairment than channels not selected for use. A visual display is preferably used to provide an indication of the assigned time slot on the first base transceiver.

035 Further explanation of the invention is found in the claims and detailed disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

036 There will now be described preferred embodiments of the invention, with reference to the drawings, by way of illustration only and not with the intention of limiting the scope of the invention, in which like numerals denote like elements and in which:

Figure 1 illustrates a system architecture according to the invention with a single wireless peripheral;

Figure 2 illustrates the system architecture with multiple wireless peripherals;

Figure 3 illustrates multiple wireless systems operating within a common radio frequency domain;

Figure 4a illustrates an exemplary electronic subsystem making up a wireless system;

Figure 4b illustrates a peripheral configuration of the electronic subsystem utilizing an application specific integrated circuit (ASIC) controller;

Figure 4c illustrates a base transceiver configuration of the electronic subsystem utilizing an ASIC controller;

Figure 5 illustrates overlapping radio frequency domains between base transceivers that are closely located;

Figure 6 illustrates polling volleys of multiple co-located wireless systems where the peripheral responses have been staggered to reduce interference;

Figure 7 illustrates a mixed system composed of base transceivers supporting multiple member and single member groups of associated peripherals;

Figure 8a illustrates a base transceiver polling packet format;

Figure 8b illustrates a representative example of a base transceiver polling packet format for a wireless game application;

Figure 9a illustrates a peripheral response packet format;

Figure 9b illustrates a representative example of a base transceiver response packet format for a wireless game application;

Figure 10 illustrates the reduction in signal interference by staggering the channel frequency of a remote base transceiver;

Figure 11a illustrates a synchronization packet format;

Figure 11b illustrates a representative example of a base transceiver synchronization packet format for a wireless game application;

Figure 12a illustrates how synchronization packets are added and removed as new base transceivers are added or removed from an area having overlapping radio frequency domains;

Figure 12b illustrates how base transceiver state information changes as a new base transceiver is added to the system;

Figure 13 illustrates the layered software structure and the interactions between layers for firmware for use in and embodiment of the invention;

Figure 14 illustrates the power up and radio frequency configuration process for a base transceiver;

Figure 15 illustrates the process of establishing a radio frequency wireless link between a base transceiver and a peripheral;

Figure 16 illustrates the process of resizing a connection as an example of the messaging process between the base transceiver and the peripheral;

Figure 17 illustrates the process of bit and word synchronization as new radio frequency packet is received by a transceiver;

Figure 18 illustrates the process of adjusting the poll packet start time of a first base transceiver based on a synchronization packet Start Code reference point;

Figure 19 illustrates the process of configuring multiple base transceivers with a single peripheral capacity to use a common operating frequency;

Figure 20 illustrates the process of manually changing a peripheral's time slot by applying the connection selection switch;

Figure 21 illustrates the process of adapting the signal transmission method and operating channels to counteract rising noise levels;

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS.

037   In this patent document, the word "comprising" is used in its non-limiting sense to mean that items following the word in the sentence are included and that items not specifically mentioned are not excluded. The use of the indefinite article "a" in the claims before an element means that one of the elements is specified, but does not specifically exclude others of the elements being present, unless the context clearly requires that there be one and only one of the elements. The terms "data" or "information" or "signals" refer to an electrical or electromagnetic signal carrying data. The term "colocated" means located in sufficient proximity that signal transmission from one transceiver interferes with signal transmission from another. The term "clash" or "collide" or "collision" refers to interference between signals received at a transceiver that impairs reception to such an extent to render use of the signal impractical. A RF system or base transceiver or peripheral transceiver is a combination of elements including RF section, processor and input/ouput subsystem. An RF section comprises a transceiver and receiver, a receive signal strength indicator (RSSI) for detecting signal strength, and associated equipment.

038   The RF system described here in its various aspects provides a unique solution for home and local area business environment radio frequency wireless applications. It provides a robust radio frequency solution for standalone and multiple overlapping system configurations for gaming, consumer electronic and local area data applications.

039   Referring to Figure 1, the system architecture consists of three basic components: 1) a host system 10, 2) a base transceiver 12, and 3) one or more peripheral devices 14 linked wirelessly to the base transceiver 12 in a local area. Figure 2 illustrate a system with n peripheral transceivers 14 associated with a single base transceiver 12. All the peripheral transceivers 14 may be identically constructed, differing only in their addresses.

040   One or more such systems can exist in a given local area as illustrated in Figure 3. Figure 3 shows m such systems each having 1 up to n peripherals 14 and each system communicating to every other system within range by RF listening, described below, between base transceivers 12.

041   Examples of the host system 10 include devices such as video game consoles, set top boxes, consumer electronic devices, computers and data networking equipment. Each host system 10 is interfaced to its associated base transceiver 12 by a communications link such as a conventional wired interface, typically of an electrical or optical nature. It sends commands and data to and from the base transceiver 12, which in turn will then interact with the peripheral 14.

042   The base transceiver 12 is the master of the radio frequency system. It is responsible for polling the peripherals 14 and processing their responses. It provides a mediation role between the peripherals 14 and the host system 10 by translating and interpreting the information being sent from the peripherals 14 and interacting appropriately with the host 10.

043   The base transceiver 12 may support various peripheral combinations of various types including: 1) a single peripheral 14, 2) multiple peripherals 14, or 3) peripherals 14 and sub-peripherals. A sub-peripheral is one of several components that make up a physically divisible peripheral 14. For example, a game controller might be provided with a steering device and gas pedal. The steering column may be one sub-peripheral, and the gas pedal another. Each of these devices has independent RF wireless transceivers.

044   The peripheral 14 is wirelessly linked to the base transceiver 12. It interacts with users or electronic devices in the environment through a user interface. In the case of a video game console host, the user is the person playing the game. With a set top box host, the peripheral could be a remote control, wireless keyboard or other interactive

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device. It thus has a wireless interface associated with the base transceiver and also physical and electrical interfaces interacting with the environment.

045   The base transceiver 12 and peripherals 14 are implemented using a similar overall design, as shown in Figure 4a, with variations appropriate per device. Both consist of an RF section 16 connected by a conventional communications link to a controller 18, which in turn is connected by a conventional communications link to an input/output sub-system 20. In the case of the peripheral 14, the input/output subsystem 20 is connected to the user interface, and in the case of the base transceiver 12, the input/output subsystem 20 connects to the host system 10. In the peripheral case, typical inputs for gaming and consumer electronic applications include analog and digital buttons, joysticks, triggers and audio inputs, whereas for data applications this includes data type interfaces such as RS-232, USB and others. Typical outputs handled by the peripheral include "rumble" motors for game applications, and audio, graphic, video and other data signal outputs for more generic applications, where the more generic applications are supported by additional output electronics e.g. audio amplifiers, display drivers etc..

046   The RF section 16 may be formed of a radio frequency transceiver integrated circuit 22 such as a Tokaido RF IC from Microlinear or TRF 6900 available from Texas Instruments, associated passive RF components and filters 24 linked to the RF transceiver 22, a conventional received signal strength indicator 26 (RSSI) for providing a received signal strength to the controller 18, an RF switch 28 with matching circuitry and antenna 30. The controller 18 is a special purpose ASIC (application specific integrated circuit) configured as described in this patent document and provides baseband processing and control functions.

047   The radio transceiver 22 uses a modulation method, such as frequency shift keying, and has frequency agility to support spread spectrum techniques including spreading as well as frequency agility. The RF architecture described is independent of the exact modulation technique used and frequency operation range chosen. The system uses frequencies designated by FCC rules such as the 900 MHz ISM band and the 2.4

GHz ISM band and preferably supports channel spacings of 4MHz or more. The RF System preferably supports up to 16 independent peripherals operating in a common area radio frequency operating range, but the number of peripherals can be increased by reducing their individual bandwidth allocation, by improving the modulation efficiency (more bits per hertz) or by increasing the adjacent channel isolation.

048   The RF transceiver 22 interfaces with the antenna circuitry 30 to send and receive wireless signals and may control an external RF switch 28 to control transmission direction. The RF transceiver 22 contains RSSI circuitry 26 that allows it to measure the signal strength across the entire radio frequency spectra operating band. The RF transceiver 22 is controlled by the controller 18.

049   The controller 18 provides control functions (e.g. set up, transmission direction etc.) and data to the RF transceiver 22. The controller 18 may be a 16 bit integrated microcontroller with an eight or more thread architecture. Preferably, the controller 18 includes at least 16 kwords of 2 port RAM. One port is read, the other write. External flash and RAM memory 32 may be used for booting, system operation and to store operating parameters between uses. The controller 18 also includes conventional ROM 19 to contain a boot loader and baseband decode tables. Preferably, the controller 18 has a clock rate of at least 12 MHz, divided between the available threads. Each thread is responsible for parallel time critical tasks performed by the ASIC e.g. receiving and transmitting radio signals and communicating with the host. The controller might also alternately be implemented with a sufficiently fast microcontroller or similar device also supporting input/output functions.

050   Firmware implementing the methods described here may be written in C and loaded through the flash memory 32 to a processor core 108 shown in Figs. 4b and 4c. As shown in Figure 13, firmware for the controller is organized in three layers: 1) a radio frequency (RF) layer 110, 2) an adaptation layer 112, and 3) an application layer 114. Because of the layered structure, implementation specific details can be changed relatively easily on a per layer basis. Using multi-thread architecture, each layer 110, 112, 114 executes in parallel on one or more separate execution threads and coordinates

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operations with other layers using message passing. The RF layer 110 is responsible for establishing, maintaining and tearing down connections. The adaptation layer 112 performs data translation, compression and verification e.g. voice compression, converting controller data into a format understood by a host system application. The application layer 114 controls all interfaces external to the system, except the RF interfaces which are controlled directly by the RF layer, is responsible for the power up sequence and coordinates other global functions of the system such as device inventories, resets and upgrades. Both adaptation and application layers are "application" specific and hence change with each particular application. The functions performed by the RF layer are common to all applications and are the subject of this invention.

051   Interactions between layers, such as between the RF layer 110 of one device and the RF layer 110 on a second device, are controlled using a series of messages. This messaging system allows the various layers to operate without interfering with each other. Messages are included as payload in the overall packet structures described below.

052   RF to RF layer messages occur between the RF layers 110 of two respective devices, and are used mainly for maintenance of connection-oriented communications and to provide a data carrying function for messages of higher layers. These messages always come in pairs and are always originated from a base transceiver 12. The table below shows the various RF messages supported by the system. Messages originate from the base transceiver 12 and are replied to by the peripheral 14. Base transceiver (BT) messages are prefixed by "bt" and peripheral (P) messages are prefixed by "p". As with all messages, message IDs (identifiers) are used to identify the message type. During start up, mating numbers (device identification numbers) are exchanged and then a short mating number is assigned to identify a given established connection e.g. an RF link between a base transceiver 12 and an individual peripheral 14. Frequency hopping of peripherals is coordinated by the base transceiver through channel change commands.

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Table 1

RF to RF Messages

MESSAGE	PURPOSE	PARAMETERS	EXPECTED RESPONSE
BtJOIN	Base transceiver requests peripheral to join a base transceiver	Message ID, BT mating number, offered peripheral time slot, polling period, expected packet length, Host type, firmware and protocol version	PJOIN
PJOIN	Peripheral indicates it wishes to join the base transceiver	Message ID, BT mating number, P mating number, peripheral type, firmware and protocol version, manual join flag (indicates a user-activated switch operation prompted a new join)	btJOIN_ACCEPT
btJOIN_ACCEPT	Acceptance of a pJOIN request. The peripheral can join or reject the connection.	Message ID, BT mating number, P mating number, timeslot, short mating number, pass/fail flag	pJOIN_ACCEPT or pCLOSE_CONNECTION
pJOIN_ACCEPT	Peripheral accepts the conditions of a given channel.	Message ID, BT mating number, P mating number, timeslot, short mating number	None
btCLOSE_CONNECTION	Sent by the base transceiver wanting to close a connection	Message ID, closing settings, short mating number	pCLOSE_CONNECTION
pCLOSE_CONNECTION	Sent by the peripheral to confirm connection closure.	Message ID, closing settings, short mating number	None
btRESIZE_CONNECTION	Sent by the base transceiver to resize a connection.	Message ID, short mating number, new connection size (expected payload size) or rate (less payload per poll volley)	pRESIZE_CONNECTION
pRESIZE_CONNECTION	Sent by the peripheral to acknowledge a resized connection.	Message ID (with embedded flag to confirm resize accepted), short mating number, new connection size	None
btIDLE	Message sent by base transceiver to maintain a data link when no data is to be transmitted.	Message ID, short mating number	None
pIDLE	Message sent by peripheral to maintain a data link when no data is to be transmitted.	Message ID, short mating number	None

btCHANNEL_CHANGE	Base transceiver request to a peripheral to change a channel for frequency hopping purposes. This message can be sent twice, once to request commitment and then again to commit to a channel change on the next polling volley or just once to commit.	Message ID, new channel number, request/commit state, short mating number	pCHANNEL_CHANGE
pCHANNEL_CHANGE	Sent by the peripheral to acknowledge a channel change request.	Message ID, new channel number, request/commit state, short mating number	None
btRESET	Sent by the base transceiver to the peripheral to request a peripheral reset as required by higher protocol layers.	Message ID, short mating number	pRESET
pRESET	Confirms peripheral reset will occur after message transmission.	Message ID, short mating number	None
btSCAN_CHANNEL	Base transceiver requests a peripheral to scan a certain channel or channels for noise and transmission activity.	Message ID, short mating number, channel(s) selection flags.	pSCAN_CHANNEL
pSCAN_CHANNEL	Peripheral acknowledges a base transceiver message.	Message ID, short mating number, error code (scan not possible).	btSCAN_RESULTS
btSCAN_RESULTS	Base transceiver requests the results of a channel scan from a given peripheral. Channel results are requested using channel flags.	Message ID, channel flags, short mating number	pSCAN_RESULTS
pSCAN_RESULTS	Peripheral responds with scan results	Message ID, message length, channel(s) data	None
btTEST_MODE	Base transceiver requests peripheral test to be completed. This may involved the RF and/or higher layers depending on the test nature e.g.RF loop around.	Message ID, test type, short mating number	pTEST_MODE
pTEST_MODE	Peripheral responds to the base transceiver test request.	Message ID, test type, test data results (if applicable), short mating number	None

btPOLL_DATA	Standard poll sequence message sent from the base transceiver to send data to and request data from a peripheral.	Message ID, message length, payload data, short mating number.	pPOLL_DATA
pPOLL_DATA	Standard poll sequence message sent from the peripheral to send data to and request data from a base transceiver.	Message ID, message length, payload data, short mating number.	btPOLL_DATA

053   RF layer 110 to adaptation layer 112 messages occur between adjacent layers on a single controller in order to facilitate communications between the two layers. These messages are used primarily to request and to obtain information about connection changes, to send and receive data to the RF layer 110 for transmission, and to facilitate testing. These messages are typically paired. The table below shows a representative example of RF to adaptation messages needed to support RF layer 110 operations. The exact format and content of these messages changes depending on the application type supported. The messages shown are for a game peripheral application.

054   Adaptation to RF layer messages are prefixed by "a" and RF to adaptation layer messages are prefixed by "r". The exact message sequence depends on whether the message flow starts in the base transceiver or in the peripheral or in one layer or another. For example, a rRESIZE message may be issued by the RF layer 110 to the adaptation layer 112 to tell this layer it has resized the connection to adapt to transmission problems or the application layer may initiate a connection size change to accommodate greater data throughput. To illustrate the process, shown in Figure 16, of message passing for the application layer initiated case, the base transceiver application layer issues an apRESIZE message to the adaptation layer. The adaptation layer then issues an aRESIZE command to the RF layer (116). The RF layer arranges for the RF link resize by messaging with the peripheral by sending the btRESIZE_CONNECTION message 118.

055   The RF layer of the peripheral then informs the peripheral higher layers of the change using the rRESIZE and adRESIZE messages upward to request the resize 120

and then apRESIZE and aRESIZE commands back down to the peripheral RF layer 122. Upon receiving the upper layer confirmation, the peripheral RF layer sends the pRESIZE_CONNECTION back to the base transceiver to confirm the peripheral is ready for the resizing operation. The response packet is adapted to the resize operation 124. The RF layer then confirms the operation is complete by issuing a rRESIZE message 126 to the adaptation layer and the adaptation layer issues an adRESIZE message to the application layer to confirm the change. The resized connection may then be used 128. These types of situations are seen as circular references in the "EXPECTED RESPONSE" column and reflect message flows for the base transceiver and peripherals that are mirror images of each other in certain cases.

Table 2

RF to Adaptation Messages

MESSAGE	PURPOSE	PARAMETERS	EXPECTED RESPONSE
aOPEN_CONNECTION	Adaptation layer request the RF layer to open a peripheral connection. For the base transceiver this initiates a btJOIN at the RF layer.	Message ID	RHAVE_CONNECTION
rHAVE_CONNECTION	RF layer confirms to adaptation layer that a connection is established.	Message ID, expected packet length (for buffer sizing), host type, firmware version, protocol version	None
RCHANGE_CHANNEL	RF layer informs the adaptation layer of a channel change (frequency hop). Connection lost flags are used by higher layers to turn off link status indicator lights.	Message ID, success flag, connection(s) lost flags.	None
ACLOSE_CONNECTION	Adaptation layer request the RF layer to close a connection. Initiated by base transceiver.	Message ID, short mating number, save connection settings request	RCLOSE_CONNECTION
rCLOSE_CONNECTION	RF layer informs the adaptation layer that a connection is closed.	Message ID, short mating number, error code	None
aLINK_STATUS	Adaptation layer requests link status information from the RF layer.	Message ID, short mating number	RLINK_STATUS

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rLINK_STATUS	RF layer sends link status information to the adaptation layer	Message ID, short mating number, link quality	None
aSEND_DATA	Adaptation layer requests RF layer to send data.	Message ID, short mating number, message length, data container	None, unless data sent contains an encapsulated adaptatation layer message.
rHAVE_DATA	RF layer sends data to the adaptation layer.	Message ID, short mating number, message length, data container	None, unless data sent contains an encapsulated adaptatation layer message.
ARESET	Adaptation layer to RF layer request to reset a peripheral. Reset is coordinated by the application layer.	Message ID, short mating number	rRESET
RRESET	RF layer to adaptation layer request to reset a peripheral.	Message ID, short mating number	aRESET
ARESIZE	Adaptation layer to RF layer resize a connection.	Message ID, short mating number, new connection size	rRESIZE
RRESIZE	RF to adaptation layer resize a connection.	Message ID, short mating number, new connection size	aRESIZE
AREMOTE_TEST	Adaptation layer to RF layer remote testing.	Message ID, test type (BT only), message length (P only), test data results (P only), short mating number	rREMOTE_TEST
RREMOTE_TEST	RF to adaptation layer remote testing.	Message ID, test type (P only), message length (BT only), test data results (BT only), short mating number	aREMOTE_TEST

056   Adaptation layer 112 to adaptation layer 112 messages are used for devices to share device feature information. The type and format of data collected by a peripheral is converted to a form usable by the host and vice versa. Adaptation layer messages also request the RF layer 110 to close a connection and support the upgrade process. These messages always come in pairs and are always originated from the base transceiver. The table below shows a representative example of adaptation to adaptation messages needed to support RF layer operations. The exact format and content of these messages changes depending on the application type supported. The application described is for a game peripheral. These messages are carried as a payload of the RF layer data carrying messages, btPOLL_DATA and pPOLL_DATA. Adaptation layer messages are prefixed

by "bt" for those originated at the base transceiver and prefixed by "p" for those originated at the peripheral.

Table 3

Adaptation to Adaptation

MESSAGE	PURPOSE	PARAMETERS	EXPECTED RESPONSE
BtENUMERATE	The base transceiver requests the peripheral to describe its feature set. This allows adaptation to new controller types and new controller features. All or selected feature sets may be requested.	Message ID, feature set request, sequence number, short mating number	pENUMERATE
PENUMERATE	The peripheral describes its feature set to the base transceiver.	Message ID, short mating number, sequence number, maximum sequence count, message length, feature list	None
BtCONFIGURE	The base transceiver requests the peripheral to configure its feature sets to match host interface characteristics. This message may be sent in several parts.	Message ID, short mating number, sequence number, maximum sequence count, message length, feature configuration list	pCONFIGURE
PCONFIGURE	The peripheral confirms the configuration process and provides the hardware revision number of the peripheral electronics (upgrade version identification purposes) to the base transceiver.	Message ID, short mating number, peripheral hardware ID.	None
BtGOODBYE	The base transceiver sends this message to the peripheral as part of a close connection sequence as initiated by the peripheral.	Message ID, short mating number, save settings flag	None
PGOODBYE	The peripheral sends this message to the base transceiver to request it to originate the close connection process e.g. when the connection selection switch has been pressed.	Message ID, connection selection switch flag, short mating number, save settings flag	btGOODBYE

BtUPGRADE	The base transceiver sends this message to the peripheral to initiate an upgrade of the peripheral's firmware. btPOLL_DATA is used to send upgrade information.	Message ID, short mating number, peripheral hardware ID, firmware version, image length (image to follow)	pUPGRADE
PUPGRADE	The peripheral sends this message to the base transceiver to acknowledge the upgrade request. If hardware or software version numbers do not match, the attempt is rejected.	Message ID, short mating number, peripheral hardware ID, error code	None

057   Application layer to adaptation layer messages occurs between the application layer 114 and the adaptation layer 112. The application uses this interface to communicate with lower protocol layers. These messages are used to request connection changes, to send and receive data to the RF layer for transmission, to facilitate testing and system upgrades. The table below shows a representative example of application to adaptation messages needed to support RF layer operations. The exact format and content of these messages changes depending on the application type supported. The messages shown are for a game peripheral application. Messages prefixed by "ap" are originated at the application layer and messages prefixed by "ad" are originated at the adaptation layer.

Table 4

Application to Adaptation Layer

MESSAGE	PURPOSE	PARAMETERS	EXPECTED RESPONSE
ApOPEN_CONNECTION	Application layer requests the adaptation layer to open a peripheral connection. For the base transceiver this initiates a btJOIN at the RF layer.	Message ID, host interface information (BT only)	adHAVE_CONNECTION

AdHAVE_CONNECTION	Adaptation layer informs the application layer that the previous connection request is complete.	Message ID, RF port used (corresponds to connection light), peripheral type, connnection state, host interface information (BT only), peripheral version numbers.	None
AdCLOSE_CONNECTION	Adaptation layer informs the application layer that a connection (one of several for the BT) is closed.	Message ID, error code, RF port used (BT only)	None
ApGOODBYE	The peripheral application layer requests the adaptation layer to begin the close connection sequence when the connection selection switch is pressed -- manual RF connection change.	Message ID, connection selection switch flag (P only), RF port used (BT only)	adCLOSE_CONNECTION
apLINK_STATUS	Application layer requests the adaptation layer to obtain the link status.	Message ID, RF port used (BT only)	adLINK_STATUS
adLINK_STATUS	Adaptation layer informs the application layer about the link status check results.	Message ID, RF port used (BT only), link quality	None
AdCHANGE_CHANNEL	Adaptation layer informs the application layer about the results of a frequency hop e.g. any lost peripherals declared and the application layer turns off corresponding connection light.	Message ID, channel change pass/fail flag, peripherals found.	None
ApSEND_BUFFER	Application layer requests adaptation layer to send data to lower layers for transmission. Need to send to a targeted peripheral for the base transceiver case.	Message ID, RF port used (BT only), peripheral interface & host interface information (to direct adaptation layer data formating so the output is usable by the host or peripheral)	None
AdHAVE_BUFFER	Adaptation layer informs the application layer that new data has been sent from a lower layer.	Message ID, RF port used (BT only), peripheral interface & host interface information	None
ApRESET	Application layer command to the adaptation layer to initiate a reset.	Message ID, RF port used (BT only)	adRESET

AdRESET	Adaptation layer command used during reset. RF port number used to turn off indicator lights on BT.	Message ID, RF port used (BT only)	apRESET
ApRESIZE	Application layer asks the adaptation layer to resize a connection. Request gets passed to RF layer.	Message ID, RF port used, host information (BT only), new connection size	adRESIZE
AdRESIZE	Adaptation layer informs the application layer about resize event. This is a confirmation in the BT case.	Message ID, RF port used, host information (BT only), new connection size	apRESIZE
ApREMOTE_TEST	Application layer test message to the adaptation layer for a remote peripheral.	Message ID, test type (BT only), data length (P only), test data results (P only), RF port used	adREMOTE_TEST
AdREMOTE_TEST	Adaptation layer test message to the application layer for a remote peripheral.	Message ID, test type (P only), data length (BT only), test data results (BT only), RF port used	apREMOTE_TEST
ApUPGRADE	Application layer to adaptation request for upgrade notification.	Message ID, peripheral hardware ID, firmware version, image length, RF port used (BT only)	adUPGRADE
AdUPGRADE	Adaptation layer to application layer request for upgrade notification.	Message ID, peripheral hardware ID, firmware version, image length, RF port used (BT only)	apUPGRADE

058   Continuing with the system description as shown in Figure 4a, the controller 18 is connected via conventional communication links to digital and analog interfaces to support host and environment interfaces (e.g. signal lights) in the base transceiver 12 and user and environment input/output in the peripheral 14. Figure 4b and Figure 4c show the controller as it is configured as a peripheral and as a base transceiver for a gaming application. The following interfaces are used: external memory interface 130, DSP serial interface (future capability to add processing capacity as required) 132, both through bus 133, RF baseband interface 134 through bus 133, analog to digital interface 136 and a general purpose digital interface 137, test interface 138 for connection to a debug system 140, host interface 142 (for example, a game console interface such as a direct parallel connection, USB interface, SPI or proprietary host-defined interface), power and clock input 144, 146 for an external oscillator and clock. The peripheral is

connected to various input devices at 148 such as game controller keys, joysticks and to output devices at 150 such as "rumble" motors and a signal connection light. For the peripheral configuration there is no host and this interface is not used. The design of each of these interfaces is dependent on the design of the device being interfaced e.g. the type of RF subsystem used or the type of host device interfaced.

059   The controller 18 is also used to convert raw data to and from the host/environment or RF transceiver. The controller firmware must be changed on a per case basis to accommodate the proprietary interface specifications of a given host device. The RF transceiver interface control functions are designed to accommodate the RF subsystem chip interface specifications of a given vendor e.g. Microlinear or Texas Instruments chip-sets as mentioned above. The RF baseband data interface 134 carries the raw digital data coming and going to the RF subsystem 16. The controller 18 directs the RF subsystem 16 to perform frequency scan operations for signal characterization purposes and performs various synchronization operations and coding functions to lock onto baseband data signals and ensure their reliable transmission.

060   Frequency scanning functions are performed using the receive signal strength indicator (RSSI) function, as seen in Figure 4a, as is found on many RF chipsets. The controller 18 directs the RF chipset to tune to a given center frequency and then RSSI measures the signal strength within the receiver's channel envelop at that center frequency. The envelop form is determined by the receiver's intermediate frequency (IF) filtering characteristics. Figure 10 shows such a receiver channel envelop. The signal strength sample can be taken in as little as 100 microseconds for some RF subsystem types. This allows a base transceiver or peripheral to scan a broad range of channel frequencies in a short interval.

061   The controller 18 uses a direct sequence spread spectrum coding method to provide an error correction capability. The controller 18 is implemented to support multiple parallel threads or processors. Two of these threads are dedicated to such baseband processing. In order to increase the robustness of the system and to assist with the synchronization function, a well known direct sequence spreading code method is

preferably used, although other coding methods might also be used in a similar fashion. When a buffer of raw data is being prepared for transmission, sequences of 2, 4 or more bits are mapped to a set of 16 bit spreading codes. The system transmits codes to represent actual signal bits over the RF link to give the transmitted signal several desirable characteristics. Codes are chosen based on selection conditions to maximize the "Hamming distance" between elements within a code set, to have zero D.C. offset, to support defined bit run-length characteristics, and to support error-correction. Hamming distance is defined as the number of bit differences found when the logical exclusive-OR function is performed on any two codes from a code set. A Hamming distance of 3 is desired between any two codes in a code set and a frame start code should preferably have a Hamming distance of 8 from an alternating 0,1 preamble sequence used for synchronization purposes. The larger the code distance, the easier it is to differentiate codes at the receiving end even if they are partially corrupted.

062   At the receiving end, received codes are compared against known spreading codes and converted back into the original bit sequence. Because code types are chosen to have known bit differences, the received code, even if 1 or more bits are corrupted, can be matched successfully to a reference code and decoded back to the original bit sequence. Any code set satisfying the above selection conditions can be used by the system. A set consisting of 4, 16 or more, 16 bit spreading codes is required to represent any 2, 4 or longer bit sequence respectively.

063   As shown in Figure 17, the controller 18 performs bit and frame synchronization functions as each new packet arrives. All packets transmitted by the RF system are prefixed by a preamble sequence followed by a start code (217B HEX) which is the first element of a packet header. The preamble sequence is a series of up to 80 zeros and ones used to establish the packet bit and then frame timing and to train the RF receiver's D.C. offset parameters. When a new packet preamble sequence is detected by the controller, it begins to sample the incoming bit stream at a rate which is at least 8 times the frequency of a single bit time. During the preamble, multiple signal level samples are taken by the controller to detect bit transition times and hence the logical transition time and period of the incoming bit stream 152. A window, containing 16 transitions, is

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analyzed by the controller. The transition timing, bit period and relative 0/1 timing is determined by taking the average of all transitions from the 16 bit sample 154. This process only "locks" onto a bit stream when 16 zeros and ones in a row are detected. A bit counter having a count value that repeats at the center of every transmitted bit is initialized and run continuously 156. This timer is used to control when the logical value of the raw bit stream is sampled and recognized. Using the output of the sampling process, the repeat count value of this counter can be adjusted dynamically to adjust for bit timing variations.

064   Once bit timing is established the beginning of the packet frame and frame boundaries are determined. As each new bit sample is read in the preamble, a 16 bit word, consisting of the most recent 16 bits is read and decoded. The first 16 bit code after the preamble sequence is a START Code 158. This code is chosen so that it has a 8 bit difference (Hamming Distance) from the preamble sequence so that even with severe signal degradation, the first word of the packet can be easily decoded. This first word is used to set up frame or word synchronization in the message packet 160. A word counter with a period corresponding to the time taken to transmit a single word is initialized and is used to decode packets contents on their word boundaries.

065   Base transceivers 12 and peripherals 14 use bit and word synchronization to lock onto, read and derive timing information from RF packet transmissions from an arbitrary system RF transceiver. As shown in Figure 18, a first base transceiver (BT #1) can listen 162 to the synchronization packet from a second base transceiver (BT #2) that is in range, calculate a start time adjustment 164, check polling period limits if required 166 and adjust 168 its polling packet timing to occur nearly at the same time as the other base transceiver. A polling-period counter in each base transceiver controls the polling volley period length. This counter can be adjusted incrementally as required. A first base transceiver detects the start time of the START Code in the synchronization packet (see Figure 11b) of a second base transceiver and adds a known time offset to calculate the poll packet start time of the second base transceiver. An offset, used to adjust the polling-period counter of the first base transceiver, is then preferably derived from an average of the first base transceiver's polling packet start time and the start time of the

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second base transceiver, but may be any calculated amount that prevents overshoot and timing instability. Whatever solution is used, the adjustment moves toward a target value, and does not attempt to hit the target in one step. As a first base transceiver and a second base transceiver compare and adjust their polling packet start times over time, these times move toward each other. In order to guarantee the polling response time of the system, the polling-period counter is not allowed to vary beyond a defined tolerance of the 16.67 msec system-defined polling time. The appropriate value of this tolerance and polling time is application specific. Also in a given polling volley, peripherals respond in time slots that are an agreed delta time away from the Start Code of the base transceiver's polling packet.

066   In a given local area, systems of hosts 10, base transceiver 12 and associated peripherals 14 coexist. Figure 5 illustrates an example of overlapping RF domains 34 as represented by the transmission footprint of each base transceiver.

067   Referring to Figure. 14, as a base transceiver 12 powers up 36 the application layer performs a self-test and then waits for a random interval of several hundred milliseconds. This waiting interval staggers the RF activation of two or more base transceivers that are connected to a single host system. Following this, the application layer starts the RF layer (using the apOPEN_CONNECTION and then aOPEN_CONNECTION messages). The RF layer characterizes the RF spectra and searches for other base transceivers 12 in its RF operating range using RSSI hardware as described above. The base transceiver 12 looks for free RF channels and RF channels used by other base transceivers 12 (38) by scanning the available channels incrementally. The base transceiver 12 also characterizes the noise present on available channels 40 and ranks the channels in terms of impairment 42. If the base transceiver is the first base transceiver to be activated in a given RF operating range, it selects sufficiently unimpaired channels for use 44 and chooses a starting operating frequency 46 and hopping sequence 48 corresponding to the number of usable channels. The preferred hopping sequence is a pseudo random sequence (although sequential sequences can be used and are used in the examples for simplicity) the length of which depends on the number of usable channels e.g. for a system with 4 usable channels a predefined

sequence CH1, CH3, CH2, CH4 can be used based on the number of usable channels, although longer sequences that are multiples of the number of usable channels are also possible. In order to support 16 devices in a common RF operating range at least 4 channel frequencies are required. If 4 good channels are not available, impaired channels are used if possible in order of least signal impairment until 4 channels are chosen i.e. there are enough channels above a certain minimum threshold such as a signal to noise ratio of 30dB. The value of this threshold will depend on the application supported and how many errors in transmission (inverse of the grade of service) can be tolerated. The first base transceiver also chooses a predefined frequency hopping sequence for the synchronization packets based on the number of usable channels 49. The synchronization packet hopping sequence type can be the same (same start value, same length, same hop sequence), as is shown in the example in Figure 12, or different from the first base transceiver poll and response packet hopping sequence type (same or different start value, same or different length, same or different hop sequence) depending on the desired characteristics for the synchronization packet versus the poll and response packets as determined by the designer. A separate pointer is also assigned for the synchronization packet hopping sequence that can be the same or different than the pointer for the polling volley frequency hopping sequence.

068   The RF subsystem can also support variable center frequencies, hence the channel center frequencies can be predefined, or picked at the time of the first base transceiver's noise scan to avoid areas of high sustained noise. The number of possible channel center frequencies depends on the RF subsystem channel tuning resolution and for a given device it can be represented by an integer value. Information relating to the number of channels, channel selection and channel hop sequence is broadcast in the synchronization packet.

069   From the channel scan 38, when there is at least one base transceiver in the system, the new base transceiver 12 determines that other base transceivers exists and locks onto and analyzes sync signals from another base transceiver 12 (50), to determine its operating parameters such as when to start polling volleys to its associated peripherals

14 (52). These parameters are determined by analyzing the timing and content of another base transceiver's RF transmission headers and synchronization packets. .

070   After power up, the transmission channel frequency for each base transceiver channel hops in a defined sequence and with a defined hopping rate. A hopping rate of 60 hops per second is supported (channel change once per polling volley), although higher rates are possible by reducing the period of the polling volley. Frequency hopping is known in the art, and any of many known hopping patterns may be used in accordance with spread spectrum techniques.

071   Channels used by the system are continuously scanned for noise, one or a few channels at a time during operation, and are automatically not used if they cannot support any transmissions reliably. . The base transceiver sends a btSCAN_CHANNEL message to request a channel scan and peripheral acknowledges with a pSCAN_CHANNEL message. On a subsequent polling interval, the base transceiver requests the results using the btSCAN_RESULTS message and they are provided by peripheral using the pSCAN_RESULTS message. In noise situation system operation degrades gradually and the impact of this degradation is shared across all base transceivers 12 as they hop through the noisy channel or channels.

072   When degradation occurs the transmission errors can be passed uncorrected, data can be retransmitted, coding methods changed, operating channels dropped, or data rates can be dynamically decreased to increase the accuracy of a noisy channel.

073   Each base transceiver 12 uses a hopping sequence that is non-overlapping with hopping patterns of all other base transceivers 12 in the local area. The base transceiver 12 can preferably direct the frequency hops of its attached peripherals 14 using the btCHANNEL_CHANGE and pCHANNEL_CHANGE commands or they can follow the base transceiver 12 automatically in a known hopping pattern.

074   Referring to Figure 15, following power up the base transceiver 12 begins polling for peripherals 14 asking them to become associated with the base transceiver 12 by the

wireless link. Such an association is made by a join request 54 (btJOIN message) by the base transceiver 12, followed by a join acknowledge (pJOIN_message) from the peripheral 14 to tell the base transceiver that it is interesting in being associated. By convention this peripheral response is provided in the last unoccupied peripheral time slot in the polling volley. Next the base transceiver issues a btJOIN_ACCEPT message and the peripheral responds with a pJOIN_ACCEPT message, resulting in the exchange of full address and other information 56. At this point of connection initialization a short address, called a short mating number, is assigned to the peripheral's connection to the base transceiver and is used thereafter for communications. The peripheral is also assigned a time slot in the polling volley 58 and from that point onward the peripheral 14 communicates with the base transceiver 12. There is a chance that a second peripheral may have simultaneously responded to the btJOIN message with another pJOIN message. If this has occurred and this second peripheral beat the first peripheral in joining to the base transceiver, the information provided by the btJOIN_ACCEPT message will be for the second peripheral. If the first peripheral detects this situation, it stops its join process and waits a random interval before trying again i.e. responding to a new btJOIN message. This forced wait prevents join conflicts between competing peripherals.

075   A special situation can exist during initial peripheral connection, relating to whether the peripheral is of a sub-peripheral type. A peripheral can operate by itself and occupy its own time slot, can support a sub-peripheral, or can be a sub-peripheral only. Using the pJOIN message peripheral type parameter, the presence of a sub-peripheral is detected by the base transceiver. If a peripheral exists to support this sub-peripheral, the base transceiver assigns the sub-peripheral to an available sub-slot of the peripheral's response time slot and adds a sub-peripheral header/data field to its polling packet to address the new sub-peripheral. If no peripheral can support the sub-peripheral, the connection attempt is rejected by the base transceiver. In the btJOIN_ACCEPT message the pass/fail flag is set to fail. The sub-peripheral then responds with a pCLOSE_CONNECTION message to end the connection attempt.

076   Following connection set up, a list of features supported by the peripheral (e.g.number and type of buttons, joysticks, data ports) are sent to the base transceiver (btENUMERATE base transceiver message followed by pENUMERATE peripheral message) and this is compared with host requirements 57. A set of peripheral features to be used by the host is selected by the base transceiver. The base transceiver then sends configuration information to the peripheral telling it how it is to supply and receive information from the host (btCONFIGURE base transceiver message followed by a pCONFIGURE message from the peripheral). The base transceiver and peripheral adaptation layers then send adHAVE_CONNECTION messages to their respective application layers to inform them of the new connection. These layers can then perform the appropriate actions such as turning on their respective connection lights 59, notifying a host that a new peripheral has joined in the case of the base transceiver, and beginning to sample and aggregate input interface information in the case of the peripheral.

077   If the peripheral later wants to leave it requests the connection be closed or simply leaves and the base transceiver closes the connection after several polling cycles in which no response is found from the peripheral. While unused time slots remain, multiple peripherals may be added or drop off using this method.

078   The exact time slot assignment given to a peripheral is determined by the base transceiver. Time slots may be assigned in a sequential first come, first served basis, assigned in coordination with the time slots assigned to neighboring base transceivers, or assigned by an algorithm such as a generated pseudo random sequence. Time slots should not overlap with each other.

079   For example, as shown in Figure 6, in a system of base transceivers with only a few peripherals, time slots can be assigned so that all peripherals in time and on different frequencies associated with different base transceivers only respond in non-overlapping time slots. In Figure 6, a first base transceiver begins a polling volley 60 and then listens for responses 62 from peripherals 14 in the later part of a time slot schematically represented as a time interval bounded by the vertical bars 64. Corresponding polling volleys of additional base transceivers #2 and #3 are shown. Base transceiver #2 is also

shown as transmitting a sync signal 66, which the other base transceivers 12 listen for. Each time period comprising a specific polling volley and corresponding responses may be called a polling cycle.

080   Examples of different polling volleys for multiple base transceivers 12 located in the same RF domain are illustrated in Figure 7. The volley for base transceiver #1 (BT #1) shows a base transceiver system where all the peripheral time slots have been assigned and are used by respective peripherals communicating with the base transceiver #1. The volley for base transceiver #2 (BT #2) has one connected peripheral, different from the peripherals communicating with the base transceiver #1. A synchronization packet 68 is also shown. Only one such packet 68 is associated with each polling volley for a system of base transceivers having overlapping frequency domains. The sync packet 68 is transmitted by one base transceiver and used by all other base transceivers to adjust the start time of their polling volley as described above. Only one base transceiver transmits a sync packet during the time span associated with a polling volley. Each base transceiver transmits a sync packet in turn. Generally, a base transceiver transmits a sync packet each n+1 polling volleys, where n is the number of base transceivers transmitting in the domain. This leaves one polling volley without a sync packet each n+1 polling volleys. That polling volley may be used by a base transceiver seeking to commence transmitting in the domain. When a base transceiver is added or a base transceiver stops transmitting in the domain, the other base transceivers adjust their sync packet transmissions accordingly to leave one polling volley without a sync packet in each n+1 polling volleys.

081   The volley for base transceiver #3 (BT#3) has two connected peripherals. Base transceivers 4, 5, 6 and 7 (BT#4,5,6,7) are of a simpler type than base transceivers 1,2,3 and hence have a short poll packet and typically support only a single peripheral. Base transceivers 4,5,6,and 7 efficiently use a single channel thus conserving spectrum by time division multiplexing multiple poll/response pair signals together. As indicated in Figure 7, the base transceivers 4-7 transmit sequentially, one at a time on a single channel, during an initial polling volley, with each base transceiver 4-7 communicating with a different one of four peripherals using packets 70A, 70B, 70C and 70D. The

peripherals then respond in order with their response packets 72A, 72B, 72C and 72D in a later part of the time period associated with the polling volley.

082   As shown in Figure 19, the configuration process to support base transceivers of type 4 to 7 (Fig. 7) requires an additional degree of coordination. When this type of base transceiver starts up it listens to a given frequency until it finds a poll packet and a synchronization packet 170. From the synchronization packet (described below in more detail and shown in Figure 11b) it preferably discovers the existence of other base transceivers of its type from the base transceiver identification (ID) number map (BT Map) contained in the synchronization packet 172. The last four bits of the base transceiver ID number identify the number of supported peripherals. Base transceivers that support one peripheral have a value of 0 and those that support four peripherals have a value of 3. This identifier could also be contained as a separate parameter in the synchronization packet. Also the channel hop pointer associated with each base transceiver in the base transceiver map for base transceivers sharing a common frequency is the same. Using this information the new base transceiver determines if base transceivers supporting a single peripheral exists. If none do or an existing channel with multiple such base transceivers is full, it uses a new starting frequency in the frequency hopping method used by the system 174. If other base transceivers of the single peripheral type exists, the new base transceiver of this type selects a new unused base transceiver slot and peripheral slot 176. It then broadcasts this information in its synchronization packet at the appropriate polling volley interval 178 so that other base transceivers are aware, update their corresponding base transceiver maps, and avoid using these time slot assignments 180. Such a method may be used for base transceivers sharing a common frequency with more than one peripheral where sufficient time slots exist to support multiple such time division multiplexed base transceivers.

083   Although the figure illustrates base transceivers supporting up to four peripherals or only one peripheral, the number of peripherals responding per base transceiver and the number of poll/response pairs that are multiplexed can be varied in numerous configurations to suit the given application.

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084   Regardless of the polling configuration, the base transceivers 12 each send a polling packet 74 having the format shown in Figure 8a. This packet 74 contains a preamble 76, an overall base transceiver header 78 providing overall system defined control functions and peripheral poll sub-packets 80, each with a header and payload, addressed to each of the connected peripherals 14. Join and other control messages are contained in the base transceiver header or if too large can be inserted after the peripheral poll sub-packets. The preamble is used to train the peripheral receiver's bit timing and D.C. offset parameters. A frame check 82 terminates the packet 74.

085   Figure 8b shows a detailed breakdown of a representative base transceiver polling packet for a wireless game peripheral application. The header, like all system packets starts with a START Code to facilitate word boundary alignment. The POLL Packet Identifier and POLL Packet Length identify this packet to be of the POLL type and of the length indicated. The Message Type and Message Data fields support carrying global type messages such as those used during the initial connection formation (e.g. btJOIN and btJOIN_ACCEPT messages). The base transceiver SYNC Sequence Type allows the synchronization packets to follow a separate frequency hopping sequence from the base transceiver polling volley frequency hopping sequence (Channel Hop Sequence Type). The SYNC sequence pointer shows where in the hop sequence the sync signal lies. The BT SYNC Period defines the number of polling volleys between synchronization packets for a given base transceiver. The BT ID Number is the base transceiver's unique identification number. The BT Subslot Number is used to denote the subslot within which a base transceiver supporting less than 4 peripherals indicates the subslot in the poll packet time interval during which it broadcasts a polling packet. If 4 peripherals are supported this number is always 0 to denote that there is no room to share the polling packet time interval. The Channel Hop Sequence Type identifies the hopping sequence used and the Channel Hop Sequence Pointer identifies where in this sequence the base transceiver currently resides. The length of the hopping sequence can vary depending on the application. The Channel Hop Rate supports from one hop every volley (fastest and preferred setting) to one hop every n volleys. RESERVED leaves room for future features. The Peripheral Field Identifier and Peripheral Field Length mark the beginning of the peripheral header/data segments. The Peripheral Header

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contains the short mating number and peripheral data field length information at a minimum. The peripheral header is followed by the given peripheral's data field. At the end of the packet a frame check, used to detect transmission errors, is included.

086   In the case of normal peripherals each of the sub-packets applies only to the specifically addressed peripheral. In special cases, as illustrated in Figure 7 for base transceiver 7, a sub-peripheral may join the normal peripheral and share its time slot as indicated at 84. In this case multiple sub-packets addressed to a given time slot contain information for the peripheral and the sub-peripheral. An example of a sub-peripheral for a gaming application is a wireless gas-pedal for a separate main peripheral containing a steering wheel and shifter.

087   Once a base transceiver 12 has completed polling peripherals 14, each of the peripherals respond in their assigned time slots. In the case of the sub-peripheral illustrated in Figure 7, it shares surplus time slot space with another peripheral. As described above, when the sub-peripheral joins it detects the presence of a peripheral 14 that can support a sub-peripheral and joins the appropriate time slot.

088   If the user is not satisfied with the association such as in the case where the sub-peripheral could join any one of several main peripherals, the time slot can be manually changed by the user by applying the connection selection switch 86 as shown in Figure 1. The process of manually changing a connection is outlined in Figure 20. The application of the connection selection switch is detected by the application layer in the peripheral 200. This layer sends an apGOODBYE message to the adaptation layer 202. The adaptation layer then sends a pGOODBYE message to the RF layer. This message and the previous message have their selection switch flags set to yes to indicate that the event was triggered by the actuation of the connection selection switch 86. The RF layer then wraps the pGOODBYE message in a pPOLL_DATA message and transmits it wirelessly to the base transceiver. The RF layer at the base transceiver unwraps the contents and sends the pGOODBYE to the base transceiver adaptation layer 204. The base transceiver adaptation layer generates a btGOODBYE message and sends it to the base transceiver RF layer for transmission within a btPOLL_DATA message 206. The

btGOODBYE message is received by the peripheral, unpacked by the peripheral RF layer and recognized by the adaptation layer. The peripheral is thus aware that the connection will be closed shortly and the base transceiver understands that this closure was due to the actuation of the connection selection switch 208. The base transceiver prepares for both closing the connection and expecting a new join attempt by the peripheral.

089   The base transceiver then closes the connection to the peripheral, turns off its connection light for the peripheral and begins polling for the peripheral to rejoin the base transceiver 210. To close the connection the base transceiver adaptation layer sends an aCLOSE_CONNECTION message with instructions to save the time slots of previously attempted joins from this peripheral. The base transceiver RF layer then constructs a btCLOSE_CONNECTION message and transmits it RF wirelessly to the RF layer of the peripheral. The peripheral RF layer sends a rCLOSE_CONNECTION message to the peripheral's adaptation layer 212. The adaptation layer sends an adCLOSE_CONNECTION message to the peripheral application layer and the application layer notes that the connection has been closed and turns off a connection light 214, as shown in Figure 1, if it is present. The peripheral RF layer then constructs a pCLOSE_CONNECTION message and sends this RF wirelessly to the base transceiver RF layer to indicate the connection is closed from the peripheral end 216. The base transceiver RF layer constructs a rCLOSE_CONNECTION message and sends this to the base transceiver adaptation layer 218. The base transceiver adaptation layer constructs an adCLOSE_CONNECTION message and sends this to the base transceiver application layer. The base transceiver application layer notes the connection is closed, notifies the host system and turns off the connection light associated with this connection 220. Back at the base transceiver RF layer a btJOIN message is sent out, inviting the peripheral to join a new time slot, where such time slot is mapped to a different physical or logical port on the host system 222. During the new join operation, the base transceiver remembers the reason for the previous connection closure as denoted by the received selection switch flag. When the same peripheral tries to rejoin, the base transceiver thus attempts to place it in another time slot that the peripheral did not previously occupy 224. Likewise the peripheral attempts to rejoin the same base

transceiver, rather than responding to potentially other join requests from other base transceivers. If no new time slots are available, the base transceiver btJOIN message offers a time slot previously used by the peripheral. In this case the peripheral begins to search for new base transceivers to join 226, 228, coming back to this base transceiver only when these options have been exhausted.

090   If the user is still not satisfied with the peripheral time slot assignment, shown visually with a light on the base transceiver 12, the time slot can be manually changed again by the user by applying the connection selection switch 86 as shown in Figure 1.

091   The format of a peripheral response packet 88 is shown in Figure 9a. The packet 88 consists of a preamble 90 followed by a peripheral header 92 and a peripheral data component 94. The header 92 contains the connection address and other control information. A frame check 95 terminates the packet 88.

092   Figure 9b shows a detailed breakdown of a representative peripheral response packet for a wireless game peripheral application. The header, like all system packets starts with a START Code to facilitate word boundary alignment. The RESPONSE Packet Identifier and RESPONSE Packet Length identify this packet to be of the RESPONSE type and of the length indicated. The Short Form Mating ID is the short address assigned during the connection of the peripheral to the base transceiver. RESERVED leaves room for future features. The RESPONSE DATA PAYLOAD is composed of a message composed of Message Type, Message Length and Message Data fields. At the end of the packet a frame check, used to detect transmission errors, is included.

093   Radio frequency device coordination between base transceivers is supported by the exemplary RF system described here. Coordination occurs in two situations: 1) when a new base transceiver is started up and, 2) when a system of base transceivers is running in steady state operation. The transmissions of base transceivers in close vicinity are synchronized so that adjacent base transceivers do not saturate each other's receivers during polling transmissions. The method of listening and synchronization of polling

transmissions between base transceivers running in steady state operation is covered in detail previously in the description of the preferred embodiments.

094   Whenever a new base transceiver 12 is powered up it performs power up and start up sequences. During this process it scans the radio frequency spectrum to record any base transceivers 12 that are already operating on given frequencies and to characterize the transmission quality of available channels. The selection of operating channels is selected by the first base transceiver in a given radio frequency operating range, and this information is broadcast to and recorded by newly joining base transceivers who listen to its synchronization packet. Information contained in the synchronization packet greatly simplifies the discovery and joining process for new base transceivers.

095   In each base transceiver synchronization packet and also in the poll packet, information identifying the frequency hopping sequence of each base transceiver is stored. The new base transceiver uses this information to track and read information from adjacent base transceivers to help it select its hopping sequence.

096   By capturing one complete synchronization packet from one base transceiver in the system, a new base transceiver gathers enough information about all other base transceivers in the system to allow it to begin operating in an unused hopping sequence starting point.

097   A palette of good operating frequencies is recorded from the Channel List field of the synchronization packet as shown in Figure 11b. Next, also with reference to Figure 11b, by examining the Channel Hop parameters (Channel Hop Sequence Type, Channel Hop Sequence Pointer, and Channel Hop Rate) and the Channel Hop Pointers already used in the BT Map field, a hopping sequence is chosen that does not clash with frequencies used by other base transceivers 12 in the domain. For example, if sequences 1-2-3-4 and 2-3-4-1 are in use, a new base transceiver might use frequencies 3-4-1-2. As described previously, the base transceiver 12 listens to any other base transceivers 12 and

synchronizes its polling volley with others who are in close vicinity within its RF domain.

098   The new base transceiver 12 uses its RSSI circuitry 26 to detect relative base transceiver distances.   If all base transceivers 12 are not in close vicinity to the new base transceiver 12, but are still detectable, the new base transceiver 12 can slightly shift its center frequency to reduce potential interference.   Thereafter it operates independently with no further synchronization requirement.

099   Figure 10 illustrates this situation.   Two local base transceivers #1 and #2 are operating on channels 1 and 2.   A remote base transceiver starts up initially on channel 1 and detects that base transceiver #1 is beyond a certain distance by using its RSSI function to measure the signal strength of base transceiver #1's transmission e.g. an RSSI voltage corresponding to a -50dBm signal would mean base transceiver is nearly out of range.   The remote base transceiver then shifts its operating channel to be between the two channels 1 and 2 respectively used by the local base transceivers #1 and #2.   In this position the remote base transceiver signal is outside of the primary band area of both local base transceivers #1 and #2 and hence negligible interference occurs.

100   In any system containing multiple base transceiver systems having overlapping RF domains, as illustrated in Figure 7, only one synchronization packet 68 is present for all base transceivers 12 in association with any one polling volley.   All base transceivers 12 not producing a synchronization packet 68 at a given time listen to the synchronization packet 68 of the designated base transceiver 12 and adjust their polling timing by a small increment.

101   The format of the synchronization packet 68 is shown in Figure 11a. Synchronization packets 68 contain a preamble 96 for receiver training, a header 98, a payload 100 and a 16 bit CRC 102 for error detection.   The synchronization packet payload 100 contains frequency hopping IDs to identify the hopping pattern, hopping rate, time slot allocation of associated peripherals, and inter-base transceiver control and data messages.

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102 Figure 11b shows a detailed breakdown of a representative base transceiver synchronization packet for a wireless game peripheral application. The header, like all system packets starts with a START Code to facilitate word boundary alignment. This code is chosen to be a member of all the direct sequence code sets used by the system and hence appears regardless of the coding method used for the contents of any system packet. All fields in the remainder of the packet are encoded using the direct sequence code set currently enabled. The SYNC Packet Identifier and SYNC Packet Length identify this packet to be of the SYNC type and of the length indicated. The Code Type Used field identifies the type of direct sequence code set used by the system and is a second check for the automatic code-set-detection capability built into the system.

103 Automatic code-set-detection is supported by the system. Due to the parallel nature of the controller, a packet can be decoded using multiple code sets. If the correct code set is chosen, the number of decode errors is small i.e. the number of bit-errors found while matching received bits to a defined code set is small. Also for the correct code set, the SYNC Length in bytes field matches the number of bits decoded. As a further check, the Code Type Used field will match the code set type identifier of the code set chosen for decoding and the CRC will be correct for the correct decoding. Using these multiple detection methods, the correct code set to use for decoding versus the incorrect code set can easily be determined. Automatic code-set-detection can decode code types having either different error correction capabilities or different codes with similar error correction capabilities. Due to the computational burden and parallel hardware costs, the system preferably can decode and differentiate 3 code sets having one, two and three bit-error correction capabilities. Such code sets are of the 4:16, 6:16 and 9:16 variety (raw input bits to code size). Decoding and differentiating more code sets is possible with more parallel hardware and/or faster processors.

104 The code type used is set by the first base transceiver that powers up in a RF operating range based upon the noise scan characterization it does upon initial power up. If the noise level in a RF operating range is found to be low, the code type chosen supports single bit error correction (9:16 code) and maximizes the transmission

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throughput. If a line rate of 1.5Mchips per second is supported, this means that the system has a 9/16 times 1.5 Mchips per second or 844 kbits per second maximum data transmission throughput. If the noise level is high, e.g. less than 20dB of signal to noise separation, or the desired noise immunity high, a code type is chosen that supports three bit error correction (4:16 code) and thus supports sub-optimal but best-effort transmission throughput of 375 kbits per second for a line rate of 1.5Mchips per second. If during normal operation, the general level of environmental noise increases or decreases, the code set used can be changed dynamically. The base transceiver detecting the change in noise switches to a new code set before it broadcasts a synchronization packet at the appropriate time. All other base transceivers listen to this synchronization packet broadcast, detect the change in codes and confirm the code type from the Code Type Used field. Thereafter all members of the system begin using the new code set.

105   Continuing on with the SYNC Packet field description based on Figure 11b, the RESERVED field leaves room for future features. Following this is the APPLICATION DATA portion of the packet. The order in which the synchronization packet is broadcast is the same order in which the base transceivers are represented in the BT Map portion of the synchronization packet. As shown in Figure 11b, if the synchronization packet shown was broadcast by base transceiver 2 (BT ID #2 in the BT Map list), the next polling volley would contain no synchronization packet, because the entry in the BT Map list is a NULL value. The hop pointers values of the NULL entry are used by a new base transceiver joining the existing base transceivers to determine the next unused starting point on the frequency hopping sequences for the poll packet and synchronization packets. All synchronization packets of all existing base transceivers mirror this information, so a new base transceiver merely needs to find one synchronization packet to get sufficient information to join the system.

106   Channel and hop information about the base transceiver that is transmitting the synchronization packet is included in the packet. The synchronization packet sequence, synchronization packet hop pointer, and period between synchronization packets is found in the SYNC Sequence Type, SYNC Sequence Pointer and BT Sync Period fields respectively. Next the BT ID Number is the unique identification number for the base

transceiver, where the last four bits indicate if this base transceiver can share the poll packet portion of the polling volley time slot with other base transceivers. A value of 0 indicates one base transceiver per hop frequency. A value of 3 indicates four base transceivers of this type can share a given hop frequency (see Figure 7, base transceivers #4 to #7). The BT Subslot Number tells other base transceivers what subslot this base transceiver occupies in the polling packet portion of the polling volley time slot. The number of channels used by the base transceivers in a RF operating range and the channel list indicating center frequencies of these channels is contained in the Number of Channels and Channel List field. These parameters are set during start up operation and can be changed if a channel becomes unusable or previously unusable channels become usable. The channel hopping sequence, the currently used channel by this base transceiver (index to a channel in the sequence), and the rate at which this base transceiver changes channels in increments of polling volleys are contained in the Channel Hop Sequence Type, Channel Hop Sequence Pointer and Channel Hop Rate fields respectively.

107   The BT map fields contain information on the channel hop sequence position and sync hop position for each base transceiver 12 in the domain. The use of this information is described in more detail below in relation to Fig. 12a.

108   In the next group of fields in the synchronization packet, information about the peripherals associated with the base transceiver is optionally included. As shown in Figure 6, the peripheral map is used by second and other base transceivers to attempt to stagger their peripheral response transmissions to avoid the peripheral transmissions of the first base transmitter currently transmitting a synchronization packet. Before the peripheral map (P Map), the number of peripherals in the map and the number of time slots is defined in the Number of Peripherals and the Number of Slots fields. Next the peripheral map (P Map) field represents the peripherals associated with the base transceiver broadcasting the synchronization packet. The format of this map is the peripheral identification number followed by the time slot that it occupies in the response packet intervals. For the example shown, peripheral 4 is a sub peripheral since it shares slot 3 with peripheral 3. Peripheral type information is encoded in the last 2 bits of the

peripheral identification number or can be implicitly determined from its peripheral map representation.

109   In the last part of the synchronization packet inter-base transceiver message fields are found.   Messages to add a new base transceiver, to abandon a newly unusable channel, and to add a newly usable channel are supported with their associated message data fields (if any). The new base transceiver (New BT) message is shown in the table in Figure 12b as a new peripheral is being added. The message set can be expanded to include any such required inter-base transceiver message type.

110   The final field in the synchronization packet it the frame check field that is used to detect if any bit errors occurred in the synchronization packet.

111   Over time each base transceiver 12 serves as the synchronization source for all the other base transceivers 12 by producing a synchronization packet at non-coincident times with other base transceivers 12.   In this way the synchronization of all base transceivers 12 in the system is maintained. Self-checks are also implemented to prevent the polling interval and polling frequency of the entire system from drifting too far from the baseline polling volley period.

112   The addition of new base transceivers is coordinated from information obtained from the synchronization packet of one of the base transceivers existing in the RF operating range.   As each new base transceiver joins the base transceivers already in the RF operating range, it reads the first synchronization packet it finds.   Additional synchronization packets might also be read to add certainty to this process. Using the BT Map from the synchronization packet, the new base transceiver finds the NULL entry. The NULL entry contains the pointer to the next unused starting point in the poll packet channel hopping frequency set. The NULL entry location in the BT Map list also indicates where a polling volley without a synchronization will occur and where all other existing base transceivers are listening for the entry of a new base transceiver.   In the example synchronization packet of Figure 11b this is after base transceiver 2. The new base transceiver broadcasts its synchronization packet in this polling volley. All other

base transceivers hear the new base transceiver and adjust their BT Maps and synchronization periods to make room for the new base transceiver and also make room for another new base transceiver to join by opening up a new polling volley with no synchronization packet. If all frequencies are currently used, no NULL entry will appear in the BT Map and the new base transceiver will not be allowed to join in the RF operating range.

113   As an example of this process Figure 12a shows a radio frequency system using four channel hopping frequencies in which another base transceiver #2 is added and the synchronization packets 68 are adjusted to support this addition. During each polling interval the frequency of each base transceiver #1, #2 changes as it hops through the defined frequency sequence (1-2-3-4). The sequence shown is representative only and does not necessarily represent a linear sequence of frequency changes.

114   Figure 12b is a tabular summary of each of the important system during the polling volley when BT #2 is added to the system in line 106 of Figure 12a. The five polling volley numbers 103 shown at the top of Figure 12a are shown in the Polling Volley Number line 250 in the table. SYNC Channel line 252 is the channel on which a synchronization packet is being broadcast or anticipated to be broadcast. In polling volleys 1 and 2 base transceivers #1 and #2 (BT #1 and BT #2) broadcast synchronization packets on channel 1. Polling volley number 3 is a "listening" polling volley where base transceivers #1 and #2 listen to channel 1 for a new synchronization packet in case yet another new base transceiver wishes to join the system. In polling volleys 4 and 5 base transceivers #1 and #2 again broadcast a synchronization packet, this time on channel 4. The next two lines of the table are base transceivers #1 and #2 BT Map states 254 and 256. These maps of internal states are broadcast by each base transceiver in their respective synchronization packets at the appropriate polling volley times. During polling volley 1, base transceiver #1 is not aware of base transceiver #2. Base transceiver #1 BT Map for polling volley 1 shows that base transceiver #1 is currently using .channel 1 for both polling/response packets and for synchronization packets i.e. BT#1,1,1 BT Map table entry (the parameters of which are defined in Figure 11b). Pointer 1 corresponds to channel one for this example. Also in this BT Map, the

"NULL,4,4" entry shows that a synchronization packet can be introduced in the next polling volley, polling volley 2, after base transceiver #1 broadcasts its synchronization packet. This NULL entry also indicates that the channel corresponding to index pointer 4, in this case channel 4, could have been used by a new base transceiver for broadcasting both poll/response and synchronization packets and by inference that channel 1 can be used in the next polling volley 2. During polling volley 1, base transceiver #2 is listening to the synchronization packet of base transceiver #1. From base transceiver #1's synchronization packet, base transceiver #2, thus selects channel hop and synchronization pointers (1,1) for polling volley 2 and times its first synchronization packet broadcast to correspond to polling volley 2. In polling volley 2, the BT Map for base transceiver 2 is broadcast on channel 1 to base transceiver 1 (listening at this time) in a synchronization packet. The BT Map information shown for base transceiver #1 is from the beginning of the interval and hence has not been updated to reflect the reception of this synchronization packet broadcast by base transceiver 2. In polling volley 3, base transceiver #1 has heard the synchronization packet broadcast from base transceiver #2 in polling volley 2 and the BT Maps of base transceiver #1 and #2 are now synchronized to reflect the presence of two base transceivers in the system. The "Listening BTs" line 262 and "SYNC Packet Broadcasting BTs" line 264 of the table in Figure 12b shows when a given base transceiver is listening for synchronization packets from other base transceivers or alternately is broadcasting a synchronization packet. During polling volley 1 for example, base transceiver #2 is just joining the system and hence is listening to the synchronization packet being broadcast by base transceiver #1 on channel 1. In the next polling volley 2, base transceiver #1 is listening and base transceiver #2 is broadcasting a synchronization packet. In polling volley 3, both base transceivers #1 and #2 are listening etc.. The "BT #1 SYNC Period" line 258 and "BT #2 SYNC Period" line 260, also found in the broadcast synchronization packets, are the time between synchronization packet broadcasts. In polling volleys 1 and 2 base transceiver #2 is in the process of joining the system and hence base transceiver 1's period is 2 i.e. broadcast a synchronization packet every second polling volley. By polling volley 3, base transceiver 2 has joined the system and now both base transceivers have a new extended synchronization periods of 3 polling volleys. Finally the "SYNC Message BT #1" line 266 and "SYNC Message BT #2" line 268 of the table show the

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message being broadcast in a given synchronization packet i.e the Message Type and Message Data fields as shown in Figure 11b. During polling volley 2, base transceiver announces its arrival by issuing a "New BT" message.

115   The steady state is indicated at line 104. A single base transceiver #1 hops through a sequence 1-2-3-4. There are n=1 base transceivers and the base transceiver #1 emits a sync packet 68 each n+1=2 polling volleys. At all times one polling volley in time from at least one of the base transceivers has no synchronization pulse and all existing system base transceivers listen to this channel at this time. As a new base transceiver is added to the system it picks a new hopping sequence by listening to the NULL entry in the BT Map, as shown in Figure 12b, of an existing base transceiver's synchronization packet, and joins during the polling volley that has no synchronization pulse. The new base transceiver inserts a synchronization packet in this polling volley and places a "New Base Transceiver" message in the message area of its synchronization packet.

116   Specifically as shown in Figure 12a, addition of a second base transceiver #2 is shown at line 106. In the first polling volley interval base transceiver #2 listens to the synchronization packet of base transceiver #1 and establishes that no synchronization packet is generated in the polling packet transmitted on channels 2. As seen in Figure 12b, this is determined from NULL entry for the BT Map of base transceiver #1 during polling interval 1. The base transceiver #2 then waits for the polling volley associated with channel 2 of base transceiver #1 and transmits a synchronization packet 68 on channel 1 during the second polling volley interval. Base transceiver #1 hears this synchronization packet andknows that another base transceiver has arrived by its presence and the New BT message found in the synchronization packet. Base transceiver #1 then delays its next synchronization packet 68 to the next polling volley (number 4), which was to be on channel 3 but now is shifted to channel 4.

117   In general, the next and subsequent base transceivers 12 responsible for generating a synchronization packet delay their packets by one polling volley cycle to accommodate the new base transceiver and increase the period between their

synchronization packets by one polling volley. This opens up a new polling volley with no synchronization pulse so another new base transceiver 12 can be added later. As before all existing base transceivers listen during this period for any subsequent base transceivers.

118   If a base transceiver leaves the polling volley sequence, the absence of its synchronization packet is noticed by all base transceivers in the system. At this point all base transceivers roll back their synchronization packet timing by one packet and reduce the period between their synchronization packets by one polling volley. If the next base transceiver was due to generate a synchronization packet in the next packet volley and more than one base transceiver remains, it skips its synchronization packet volley to make room for subsequent base transceiver packet volleys for the first transition cycle.

119   This is illustrated at line 108 of Figure 12a. When no sync packet 68 associated with the polling volley on channel 2 is heard by base transceiver #1, it moves its sync packet 68 from the polling volley associated with channel 4 to the polling volley associated with channel 3, and then continues sending sync packets each second polling volley. Base transceiver #1 also updates its BT Map to reflect the absence of the second base transceiver.

120   Or alternatively, the next subsequent synchronization packets 68 on each of the remaining base transceivers 12 occur at the designated time, but thereafter the interval between each of the base transceivers 12 issuing synchronization packets 68 is reduced by one polling volley interval. This closes the gap left by the departing base transceiver 12 and leaves a single gap for a new base transceiver 12 to begin actively polling.

121   If all available channels are occupied, all polling volleys at all times will have one volley with a synchronization packet and hence a new base transceiver will not be allowed to operate in the same local area as the already present base transceivers. To allow operation of this base transceiver, it could be moved farther away so that it could shift it frequencies as described previously or so it would be out of range of other base transceivers.

122   When a base transceiver 12 or peripheral 14 initially starts up they both perform a complete noise scan of the usable spectrum. During this scan the background noise and the presence of active channels is detected and recorded. The peripheral shares this information with the base transceiver to which it bonds.

123   During normal operation the base transceiver 12 does progressive noise scans. Over a period of time during normal operation the base transceiver 12 will ask all of its connected peripherals 14 to scan individual channels and report back the results. The base transceiver thus receives scan results for all defined system channels after several polling volleys. In this way it has a current and dynamically updated view of the quality of all channels.

124   If a channel is found to exceed a defined noise power threshold as measured with RSSI measurements, the average noise value is recorded and the channel is marked as being degraded. As outlined in Figure 21, the channel is monitored for bit errors associated with rising noise levels 230 and additional actions are taken as the number of bit errors increase. Prior to a degraded channel being declared as unusable, an attempt is made to change spreading code values (the process of which was discussed previously) 232 so that the system operates at a slower data throughput rate and is capable of greater error correction. Data may also be retransmitted or transmitted twice in the same polling volley, depending on the delay and data throughput requirements of the application 234. As bit errors on a given channel exceed the correction capacity 236, i.e. the CRC does not match the error corrected data output of the system even with up to 3 levels of error correction, the channel is abandoned and the frequency hopping sequence adjusted 238. The first base transceiver to issue a synchronization packet after a channel is found to be unusable, but not broadcasting on the unusable channel, places a "Channel Abandon" message in the message field of the synchronization packet and changes its hopping pattern to a channel set with fewer channels. This base transceiver updates its BT Map so that it is the base transceiver pointing to the first frequency of the new hopping pattern. It also adjusts its BT Map record of the other base transceiver pointers to start them in subsequent hopping patterns. As all other base transceivers are listening to the

first base transceiver's synchronization packet, they see the change and the "Channel Abandon" message and thus adjust their BT Map and internal states as directed by the first base transceiver.

125   When a channel is abandoned, special cases exist. If the base transceivers in the RF operating range are running at one frequency below capacity, the polling volley without a synchronization packet is eliminated to make room. If the system was running using all channels simultaneously, one base transceiver is removed from the BT Map of the first base transceiver and it drops out of active operation. From that point on, the removed base transceiver listens for a new opportunity to join the system. When the noise on a channel or a new channel clears 240, the first base transceiver producing a synchronization packet following this adds another channel, changes the frequency hopping sequence as above and issues a "Channel Add" message in its synchronization packet. All other base transceivers in the system hear this change and adjust their frequency hopping sequences. A polling volley with no synchronization packet is thus created and the base transceiver that had to go into a listening mode, now rejoins the system by normal base transceiver add methods.

126   If at any time due to a lost signal or following a transition, the internal BT Map of a given base transceiver or base transceivers does not match that heard from the current synchronization packet of another, a bad transition is detected. A BT Map mismatch occurs when a channel is dropped or added, but in this situation a special transition message accompanying the transition identifies the special case. In other situations, such a mismatch coming unexpectedly is a sign that the system is in danger of using conflicting channels. To avoid frequency hop collisions, the affected base transceiver sends a btGOODBYE message to its peripherals telling them to save their association with this base transceiver and that they should try to reconnect later. The affected base transceiver then stops transmitting. The affected base transceiver listens for several polling volleys until it relearns the operational parameters of the base transceivers that continue to transmit. After a random delay interval, added to avoid contention with potentially multiple such base transceivers, the affected base transceiver rejoins the

transmitting base transceivers in the RF operating range by normal base transceiver add methods.

127   While preferred embodiments of the invention have been disclosed, immaterial changes may be made to what has been described without departing from the essence of the invention.